(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

CORRECTED VERSION

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 October 2000 (12.10.2000)

PCT

(10) International Publication Number
WO 00/60870 A1

(51) International Patent Classification[7]: H04N 7/18

(21) International Application Number: PCT/US00/09469

(22) International Filing Date: 10 April 2000 (10.04.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/128,613 8 April 1999 (08.04.1999) US

(71) Applicant *(for all designated States except US)*: **INTERNET PICTURES CORPORATION** [US/US]; Suite 100, 1009 Commerce Park Drive, Oak Ridge, TN 37830 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **ZIMMERMANN, Steven, D.** [US/US]; Internet Pictures Corporation, Suite 100, 1009 Commerce Park Drive, Oak Ridge, TN 37830 (US). **GOURLEY, Christopher, Shannon** [US/US]; c/o Internet Pictures Corporation, Suite 100, 1009 Commerce Park Drive, Oak Ridge, TN 37830 (US).

(74) Agents: **GLEMBOCKI, Christopher, R.** et al.; Banner & Witcoff, Ltd., 11th floor, 1001 G. Street, N.W., Washington, DC 20001-4597 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

(48) Date of publication of this corrected version:
4 April 2002

(15) Information about Correction:
see PCT Gazette No. 14/2002 of 4 April 2002, Section II

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 00/60870 A1

(54) Title: REMOTE CONTROLLED PLATFORM FOR CAMERA

(57) Abstract: A 360° full motion video camera is mounted on a support which is secured to a remotely operated vehicle, thereby spacing the camera from the vehicle. Control of the motion of the vehicle is based on the 360° view obtained from the camera. In a preferred embodiment, the camera comprises two 180° lenses, each lens comprising 10 elements formed in six groups.

REMOTE CONTROLLED PLATFORM FOR CAMERA

INTRODUCTION

The present invention is directed to a platform for a 360° video camera, and, more particularly, to a 360° video camera mounted to a remotely operated vehicle.

RELATED APPLICATIONS

1. U.S. Patent Application Serial No., (Attorney Docket No. 01096.84954) entitled "Immersive Video Presentations".

2. U.S. Patent Application Serial No., (Attorney Docket No. 01096.86942) entitled "Virtual Theater".

3. U.S. Patent Application Serial No., (Attorney Docket No. 01096.86949) entitled "Method and Apparatus for Providing Virtual Processing Effects for Wide-Angle Video Images".

BACKGROUND

Devices are known for mounting cameras to unmanned vehicles for remote observation. U.S. Patent No. 5,497,960 describes a camera mounted to a remotely controlled helicopter. The viewing image of the camera is strictly in a single direction, and the vehicle must be moved in order to obtain a view in different directions. U.S. Patent No. 4,549,208 describes a picture processing unit using a television camera and a convex mirror mounted

to a moving system. Such known devices lack the capability of providing a 360° view about the vehicle without rotation or movement of the vehicle itself, and, therefore, a limited ability to avoid objects in the path of the vehicle. Also, with known devices, the footprint of the vehicle blocks a portion of the camera's view.

On the other hand, hemispherical image capture and real-time perspective correction in response to user inputs is known from US Patent No. 5,185,667 (RE 36,207) and spherical photography including the seaming of hemispherical images together to form a spherical image is known from US Patent No. 6,002,430. Other related patents include US Patent No. 5,990,941, 5,877,801 and 5,764,276.

It is an object of the present invention to provide a remote platform for a camera which reduces or wholly overcomes some or all of the difficulties inherent in known devices including footprint removal, steering the remote vehicle away from proximate objects that may cause damage to the vehicle in the event of a collision and making sure the unmanned vehicle may be located and does not travel out of boundaries. Particular objects and advantages of the invention will be apparent to those skilled in the art, that is, those who are knowledgeable or experienced in this field of technology, in view of the following disclosure of the invention and detailed description of preferred embodiments.

SUMMARY

According to the principles of the present invention, a remotely operated unmanned vehicle has a camera with at least a pair of lenses, or a pair of cameras each with a lens arranged to provide a 360 degree spherical image. The vehicle may be a ground-based vehicle or deep sea vehicle tethered or untethered by a control/response wired link or a wireless link to a control station (Figure 13). In an airborn vehicle, preferably radio frequency or wireless communication is used to control and receive feedback from the vehicle.

In a three lens camera embodiment, the lenses are in 120 degree relationship to one another and in the same plane and in a four lens embodiment, the lenses may be as oppositely directed as possible such that each is still in approximately 120 degree relationship to another in reference to a center point, but not in the same plane. Two cameras and their lenses are mounted in a back-to-back arrangement. When used in this disclosure and attached claims, "back-to-back" means two cameras arranged together such that the image planes of the lenses fall between each of the lenses and the optical axes of both lenses are collinear with a single line which passes through each lens and camera.

An imaging element or elements capture the images produced by the lenses. When used herein and in the claims, an "imaging element" or "imaging elements" refer to both film and area scanning devices an arrays and alternatives thereof upon which an image is focused and captured and scanned into digital memory. The captured images from each camera are stored and combined to form a single, spherical image (a final, formed image). When used

herein and in the claims, "stored" not only means to digitally store an image in a retrievable form but also means to capture the image on film.

The camera lenses are preferably fisheye lenses having at least a 180 degree field of view but may be lenses having a wide angle field of view so long as the number of lenses and arrangement of the lenses is sufficient to capture a spherical field of view, with overlap permitted (if not desirable in certain applications). Such lenses typically capture a perspectively distorted image when compared to an image that would actually be seen by a human eye.

To form the spherical image, the system includes a converter which identifies, joins, and smooths the edges (also referred to as the "seams") of the captured wide angle or hemispherical or larger image with other like images into a spherical image. When used herein and in the claims, a "converter" refers to not only a manual system (splicing by hand and airbrush image altering techniques) but also an automatic image processing system (digital processing by a computer where images are altered automatically) for combining the two images together. Where a partial overlap exists between the two or more wide angle or hemispherical or larger images, the converter, for example, in accordance with US 6,002,340, processes the partial overlap to remove the overlap and any distortion and creates a single, complete, formed spherical image. Finally, a selected portion of the spherical image may be displayed as a planar view on a personal computer using perspective correction software or hardware.

The camera is mounted on a vehicle which is remotely controlled by a user based on a portion of the image input of the camera. Since the camera provides a 360° spherical

image, a user can look in any direction from the perspective of the remote vehicle, thereby allowing the user to see all objects around the vehicle. In one embodiment the seamed image may be viewed as a circle (for one hemisphere) viewed within a second outer circle (representing the second hemisphere seamed to the first. A display of the entire image or a perspective corected portion of the image selected by the user by inputting pan, tilt, rotate and zoom commands allows the user at a control station to steer the vehicle in order to avoid bumping into objects in its path.

It is also desirable in some applications to equip the unmanned vehicle with global positioning system circuitry to report to the control station the present whereabouts of the vehicle. Such results may be compared with data from the whole spherical or selected perspective view returned to the user at the control station from the vehicle to provide the user with off course warnings and the like.

In accordance with a first aspect, a apparatus for remote viewing includes a remotely operated vehicle that includes a motor assembly for powering and controlling motion of the vehicle. A camera is secured to and spaced from the vehicle, and provides a full motion video 360° spherical image. A remote controller of a control station is linked to the motor assembly to control motion of the vehicle based on a view obtained from the camera.

Preferred embodiments of the remote platform of the present invention provide improved capabilities for controlling remote vehicles as well as reducing the size of the lenses, and, consequently, the overall size of the camera, allowing improved operability of the camera and access to small spaces with the platform and camera. These and additional

features and advantages of the invention disclosed here will be further understood from the following detailed disclosure of preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments are described in detail below with reference to the appended drawings.

Fig.1 is a perspective view of a remotely operated vehicle having a 360° camera secured thereto.

Fig. 2 is a diagrammatic view of two back-to-back cameras each capturing a greater than 180° field of view image.

Fig. 3 is a diagrammatic view of two back-to-back cameras each capturing a 180° field of view image.

Fig. 4 is a diagrammatic view of two 180° lenses capturing complementary hemispherical images and feeding them to remote cameras.

Fig. 5 is a diagrammatic elevation view, shown in exploded form, of a preferred embodiment of a lens configuration for the camera of Fig. 1.

Fig. 6 is a top plan view of an alternative embodiment of the camera of Fig. 1.

Fig. 7 is a section view, taken along lines 7-7 of Fig. 6.

Fig. 8 is a top plan view of another alternative embodiment of the camera of Fig. 1.

Fig. 9 is a section view, taken along lines 9-9 of Fig. 8.

Fig. 10 is a diagrammatic elevation view, shown in exploded form, of a telecentrically opposed lens configuration for the camera of Fig. 1.

Fig. 11 is a top plan view of an alternative embodiment of the camera of Fig. 1, having a telecentrically opposed lens configuration.

Fig. 12 is a section view, taken along lines 12-12 of Fig. 11.

Fig. 13 is a diagrammatic view of a control circuit for the remote vehicle of Fig. 1.

The figures referred to above are not drawn necessarily to scale and should be understood to present a representation of the invention, illustrative of the principles involved. Some features of the remote platform for a camera depicted in the drawings have been enlarged or distorted relative to others to facilitate explanation and understanding. The same reference numbers are used in the drawings for similar or identical components and features shown in various alternative embodiments.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

A remotely controlled vehicle 2 in accordance with the invention is shown in Fig. 1 as a small helicopter 3. While a helicopter will be described as one embodiment of an unmanned vehicle, other unmanned vehicles that may be applied in the present invention may comprise small ground-based robots or even deap sea vehicles which may or may not be tethered to a control station (Figure 13).

Helicopter 3, preferably small in size and similar to the vehicle describned in US 5,497,960 has blades 6 which provide the lifting force and forward moving force for helicopter 3. Rotor blades 8 at a tail 9 of helicopter 3 allow a pivoting of the helicopter, thereby directing its forward movement. Blades 6 are mounted on a shaft 10, which is driven by a motor assembly 4. Rotor blades 8 are also driven by motor assembly 4, via a chain (not

shown) or other suitable mechanism. Motor assembly 4 controls the flight of helicopter 3 in known fashion and further discussion of its construction is not provided here.

Camera 12 provides a full motion video 360° spherical image as described below. The primary purpose of camera 12 is to record a succession of such images to form a 360 degree image movie. Such movie need not be transmitted back to the control station. It is stored on the vehicle for future post-processing and subsequent viewing.

For example, such a 360 degree video movie may be watched with head-tracker apparatus and in a weightless chair, permitting the viewer to turn their head and view perspective crrected portions of the image that they choose to watch by the movement of their head. For example, each time a tour of Hawaii is provided, the user may see new and exciting views that they did not view the last time they viewed the 360 degree movie.

Camera 12 is mounted on one end of a support 14, such as a stalk or pole, the other end of which is secured to helicopter 3. Thus, it can be seen that the footprint of helicopter 3 interferes with a portion of the view of camera 12. By mounting camera 12 at an end of support 14, that is, spaced from helicopter 3, the footprint of helicopter 3 as perceived by camera 12 is reduced, advantageously providing a larger viewing area of the environment about the helicopter.

The illustrated embodiment describes the camera as mounted via a pole to a remotely controlled helicopter. It is to be appreciated that the mounting of a full motion 360° camera to any type of remotely controlled vehicle is considered within the scope of the invention, including, but not limited to, fixed wing aircraft, robotic devices, wheeled vehicles, and underwater vehicles with the same principle of endeavoring to minimize the footprint made

by the vehicle itself. It is also desirable to mount the camera so as to not permit the vehicle to obstruct the view obtained in the direction of movement of the vehicle.

Such a remotely operated apparatus can have a multitude of uses including, but not limited to, security and surveillance monitoring, underwater recording, pipe inspection, transportation monitoring, entertainment, sporting event coverage, medical applications, advertising, marketing, virtual theater applications, flight simulation for new pilots and education. In one application, the resultant spherical image movie, after post processing can provide a airborn tour of Hawaii. One may obtain the experience of flying since the helicopter may be erased from the post-processed image. As described above, with a helmet-likje head-tracker, as known in the art, the user moves the direction of their view to the left and right and automatically is shown left and right perspective corrected views selcted by the head movement of the captured 360 degree movie experience. Of course, the user may even view the image above, behind and below them, since the captured spherical image captures an entire scene with respect to a point in time and in relation to the velocity of the vehicle or a selected velocity of flight.

In Fig. 2, camera 12 includes body 20 (which may include two cameras) connected to two or more lenses 22 and 24 (with image planes B and C, respectively). Each of lenses 22 and 23 may have fields of view greater than 180° so as to have desirable overlap. Placed in a back-to-back arrangement where the lenses are mounted such that the image planes B and C from the lenses fall between each of the lenses, and both lenses' optical axes A coincide in a single line which passes through each lens and camera, they capture the spherical image surrounding the camera body 20. It should be noted, however, that the

thickness of the camera body 20 plays a role in how much of the spherical image surrounding the camera is captured. Specifically, the objects on the sides of the camera may or may not be completely photographed depending on their distances from the camera body 20. For example, if objects are within boundary 26, some of the objects may fall into the camera's blind spots 28 and not be completely photographed. On the other hand, because of the converging angles of lenses' greater than 180° fields of view, objects within sectors 29 will be photographed twice: first, by means of the image captured by lens 22 and, second, by means of the image captured by lens 24. Decreasing the distances between the lenses reduces blind spots 28 of the spherical capture system. In this example, reducing the distance between the lenses means reducing the thickness of the camera body 20. Reducing the camera body thickness can be accomplished, as discussed below, by varying the lens configuration, or by using smaller imaging and recording elements as disclosed in U.S. Pat. No. 6,002,430, the entire contents of which are expressly incorporated herein by reference. Additionally, the distance between image planes B and C of lenses 22 and 24, respectively, may be reduced to the point where the image planes substantially coincide, further reducing the thickness of the camera body.

Fig. 3 discloses camera body 30, similar to that of camera body 20, and lenses 32 and 34 with image planes D and E, respectively, each having a field-of-view of exactly 180°. Lens 32 receives the image of hemisphere 36 and lens 34 receives the image of hemisphere 38. The lenses 32, 34 are attached to camera body 30 in a back-to-back arrangement where the lenses are mounted such that the image planes D and E from the lenses fall between each of the lenses and both lenses' optical axes A coincide in a single line which passes through

each lens and camera. Because camera body 30 has a thickness (i.e., the distance between lenses 32 and 34 is greater than zero), the image capture system has blind spots 39 on the sides of the camera body 30. These blind spots may be reduced by decreasing the distance between lenses 32 and 34. Decreasing the distance between lens 32 and 34 requires reducing the thickness of camera body 30 which may be accomplished, inter alia, by altering the configuration of the lenses, or reducing the size of the imaging and recording components.

In FIG. 4, two cameras 40 and 42 equipped with lenses 44, 46, each located remotely from its camera body and having a field-of-view (FOV) greater than 180°. Lenses 44, 46 are arranged in a back-to-back arrangement (the image planes F, G) falling between each of the lenses and the optical axes of the lenses 44 and 46 are collinear as designated by line A). Because each camera 40, 42 has a lens (44, 46) which has a field-of-view (FOV) greater than 180°, each captures more than the image of a complete hemisphere. By employing two cameras in this arrangement, the camera system captures a complete spherical image. The types of cameras employed are motion picture cameras with loaded film or digital image capture, or other cameras as disclosed in U.S. Pat. No. 6,002,430. The outputs of cameras 40 and 42 connect by means of electrical, optical, or electro-optical links 48 to hemispherical-to-spherical image converter 49. Hemispherical-to-spherical converter 49 receives the hemispherical images from cameras 40 and 42 and combines the hemispherical images into a single, complete spherical image. The edges of the two hemispherical images may be combined to form a seamless spherical image. Removing the seams from the two

hemispherical images may be accomplished in a number of ways as discussed in US 6,002,430.

Fig. 5 shows, in exploded form, an embodiment of two back-to-back 180° lenses 50, 52, each comprising a series of elements. An element, as used herein, refers to a piece of glass, or other suitable material, having a desired shape and through which light is transmitted. The elements of lenses 50, 52 are assembled in groups. A group, as used herein, refers to a contiguous member, comprising one or more elements, through which light passes. Thus, a group may be a single element, or multiple elements adhered or cemented to one another along mating surfaces. Each lens 50, 52 comprises 10 elements assembled in six groups and preferably having dimensions as shown in inches[mm]. A first group 51 comprises an element 54, a second group 53 comprises an element 56, and a third group 55 comprises an element 58 adhered to an element 60. Fourth group 57 comprises an element 62 adhered to an element 64, fifth group 59 comprises an element 66 adhered to an element 68, and the sixth group 61 comprises an element 70 adhered to an element 72. In a preferred embodiment, element 54 is convex-concave, element 56 is convex-concave, element 58 is convex-convex, element 60 is concave-concave, element 62 is convex-concave, element 64 is convex-convex, element 66 is convex-convex, element 68 is concave-convex, element 70 is convex-concave, and element 72 is convex-convex. The shape of each element may vary depending on the characteristics of a particular lens, and suitable shapes will become readily apparent to those skilled in the art, given the benefit of this disclosure.

An iris 71 is positioned between fifth group 59 and sixth group 61. Light, shown by arrows H enters lenses 50, 52, is refracted as it passes through each of the groups, and then

strikes a triangular reflecting prism 74 having reflective surfaces 73, 75, each of which reflects the light H from lenses 50, 52, respectively, in substantially the same direction to a sensor interface 76 of the camera, producing images 77 and 79. Sensor interface 76 may be a film plane, a CCD array or other suitable interface. From sensor interface 76, the image is processed by an image processing system 85, which transforms the image to provide the proper perspective, correcting for the distorted fisheye view of the lenses. Such an image processing system was first disclosed in greater detail in US 5,185,667 (now, US RE36,207), US 5,313,306, US 5,359,363 and US 5,384,588.

An advantage with this particular construction of lenses 50, 52, is that a single sensing interface 76 can be used to pick up the transmitted image. In certain preferred embodiments, the diameter of each element 54 is approximately 48mm, the spacing between the centers of images 77 and 79 is approximately 12.7mm, and the back focal length of the lenses is approximately 11.4mm.

Another embodiment showing two back-to-back 180° lenses 86, 88 mounted in a camera housing 90, is shown in Figs. 6 and 7, with preferred dimensions being shown in inches[mm]. In this embodiment, light of lenses 86 and 88 passes through first group 51, second group 53, and third group 55, and then is reflected by reflecting surfaces 73, 75, respectively, of prism 74, in substantially the same direction through fourth group 57, fifth group 59 and sixth group 61 to a single sensing interface 76.

A further embodiment showing two back-to-back 180° lenses 92, 94 mounted in a camera housing 96, is shown in Figs. 8, 9, with preferred dimensions shown in inches[mm]. This embodiment is similar to that shown in Figs. 6, 7, however, the particular dimensions

of the elements, and the configuration of the camera housing 96 are different in Figures 8 and 9, the dimensions are smaller. While decreasing the optical resolution. The lens system is made smaller and, therefore, more portable.

Another embodiment of back-to-back 180° lenses is shown in exploded form in Fig. 10, where lenses 50' and 52' are telecentrically opposed. In this embodiment, light passes through first group 51, second group 53 and third group 55 of each of lenses 50' and 52', at which point it is reflected by a splitting prism 78, having interior reflecting surfaces 81 and 83, in substantially opposite directions. The reflected light of lens 50' and 52' then passes through fourth group 57, fifth group 59, and sixth group 61 and onward to sensing interfaces 80, 82, respectively. From sensor interfaces 80, 82 the image is passed on to an appropriate image processing system as noted above. By providing splitting prism 78 and reflecting the light from lenses 50' and 52' in opposite directions, the size of lens assembly can be minimized, minimizing the blind spots of the camera as discussed above. The lens arrangement of Fig. 10 is shown mounted in a housing 84 in Figs. 11 and 12, with preferred dimensions shown in inches[mm].

Fig. 13 shows an embodiment of a control circuit for controlling the movement of helicopter 3 that includes vehicle system 200 and ground system 300. Since a full motion 360° view is available at all times, the user, or pilot, need not steer the helicopter in any particular direction to obtain a desired view. That is, the view available to the user is independent of the direction in which the helicopter is flying.

Ground system 300 includes control station 100, display 102, input device 104, transmitter 106 and the image processing system 85. Vehicle system 200 of helicopter 3

includes the camera 12, the motor assembly 4, receiver 108, GPS locator 110, transmitter 112 and stage device 114.

The user has a control station 100 at which they are able to view an image obtained from camera 12 on display 102. Display 102 may be a cathode ray tube, a head-mounted viewing system, or any other suitable display. Control station 100 is linked to image processing system 85 so that the user may obtain a view in any direction about the helicopter. An input device 104, such as a keyboard, joystick, or other suitable input device, allows the user to instruct image processing system 85 as to which view is desired. The user can control motion of the helicopter by inputting flight control instructions through input device 104 as well. Transmitter 106 sends a signal S to a receiver 108 on helicopter 3, carrying the user's instructions for control of the helicopter. Signal S is typically a radio signal, however, other suitable signal types will become readily apparent to those skilled in the art, given the benefit of this disclosure. The control instructions are forwarded to motor assembly 4 which controls movement of helicopter in a known fashion, based on the instructions of the user. It is to be appreciated that a similar arrangement will be used for controlling the movement of other types of remote vehicles.

In certain preferred embodiments, a GPS locator 110 is positioned in helicopter 3. GPS locator 110 can be used for supplemental control of the helicopter. For example, certain predetermined parameters restricting the flight of the helicopter can be programmed through control station 100. If the user attempts to fly the helicopter beyond the parameters which have been programmed for that particular flight, control station 100 may override any further instructions of the user, keeping the flight of helicopter 3 within the boundaries set forth.

Thus, a user might be restricted to maintain a certain minimum altitude above the surface over which it is flying, or the distance of the flight may be limited as well.

A transmitter 112 on helicopter 3 sends a signal S1 carrying the images from camera 12 to image processing system 85. In certain preferred embodiments, a low resolution image, suitable for navigation purposes, may be sent by transmitter 112, while a high resolution image is stored or recorded in storage device 114, which may be, for example, a video recorder or a digital recording system.

It will be appreciated that control system and image processing system (and perhaps other systems) may be implemented in a programmable computer or in wired circuits of fixed components.

All patent applications or issued United States Patents referenced herein should be deemed to be incorproated by reference as to their entire subject matter.

Having described preferred embodiments of a novel remote camera platform (which are intended to be illustrative and not limiting), it is noted that modifications and variations can be made by persons skilled in the art in light of the above teaching. For example, helicopter 3 might be replaced with a 1920s era bi-wing stunt plane so as to generate a motion picture made of 360° spherical images that can be played back as an amusement ride where the amusement rider experiences the full 360° spherical virtural reality motion effects. Alternatively, helicopter 3 might be replaced with a small wheeled or tracked robot that is used to safely explore a radioactive contaminated or a chemical contaminated containment structure or an earthquake damaged building so that an investigator may safely study the inside of the contaminated containment or damaged building in three dimensions. It is

therefore understood that changes may be made in the particular embodiments of the invention disclosed which are within the scope and spirit of the invention as defined by the appended claims.

Having thus described the invention with the detail and particularity required by the patent laws, what is claimed and desired protected by Letters Patent is set forth in the appended claims.

What is claimed is:

1. An apparatus for remote viewing comprising:

a remotely operated vehicle that includes a motor assembly;

a camera secured to and spaced from the vehicle, the camera providing a full motion video 360° image; and

a remote controller linked to the motor assembly to control a motion of the vehicle based on a view obtained from the camera.

2. The apparatus of claim 1, wherein the remote controller is linked to the vehicle by a radio signal.

3. The apparatus of claim 1, further comprising a support secured to the vehicle and to which the camera is secured.

4. The apparatus of claim 1, wherein the camera includes a pair of back-to-back fisheye lenses, each lens having field of view of at least 180°.

5. The apparatus of claim 1, wherein the vehicle comprises a helicopter.

6. The apparatus of claim 1, wherein the remote vehicle simultaneously transmits a low resolution image of at least a portion of the viewing image of the camera and records a high resolution image of the entire viewing image of the camera.

7. The apparatus of claim 6, wherein the low resolution image is used to control the motion of the vehicle.

8. The apparatus of claim 1, further comprising a GPS locator in said vehicle.

9. The apparatus of claim 1, wherein the camera comprises two back-to-back lenses, each lens comprising six groups of elements.

10. The apparatus of claim 9, wherein a first group comprises a convex-concave element, a second group comprises a convex-concave element, a third group comprises a convex-convex element and a concave-concave element, a fourth group comprises a convex-concave element and a convex-convex element, a fifth group comprises a convex-convex element and a concave-convex element and a sixth group comprises a convex-concave element and a convex-convex element.

11. The apparatus of claim 10, further comprising a reflecting prism positioned between each of the two lenses, to reflect light passing through the elements of the two lenses in substantially the same direction.

12. The apparatus of claim 10, further comprising a splitting prism to reflect the light from the two lenses in substantially opposite directions.

13. The apparatus of claim 12, wherein the splitting prism is positioned between the third and fourth groups of each of the lenses.

14. A camera system comprising:

a ground system that includes an image processing system; and

a vehicle system that includes a camera to capture a spherical image and a transmitter coupled to transmit information derrived from the captured spherical image to the image processing system.

15. The camera system of claim 14, wherein the ground system further includes:

an input device;

a display; and

a control station coupled to the input device, the display and the image processing system,

wherein the input device provides a user selected direction to the control device, and

wherein the control system controls the image processing system to prepare a view in the user selected direction of a portion of the information for display on the display.

16. The camera system of claim 15, wherein the ground system further includes a transmitter coupled to the control system, wherein:

the control system receives a user specified movement command from the input device based on the view in the user selected direction;

the control system sends the the user specified movement command to the transmitter; and

the transmitter relays the user specified movement command to the vehicle system.

17. The camera system of claim 16, wherein the vehicle system further includes a receiver and a motor assembly, wherein:

the receiver receives the user specified movement command from the transmitter of the ground system; and

the receiver controls the motor assembly to affect movement as requested by the user specified movement command.

18. A method of controlling a camera comprising steps of:

capturing a spherical image in a camera mounted on a vehicle;

transmitting a portion of the spherical image to a ground station;

displaying a field of view image extracted from the spherical image;

sending a movement command to the vehicle based on a user's assessment of the field of view image; and

controlling the vehicle based on the movement command.

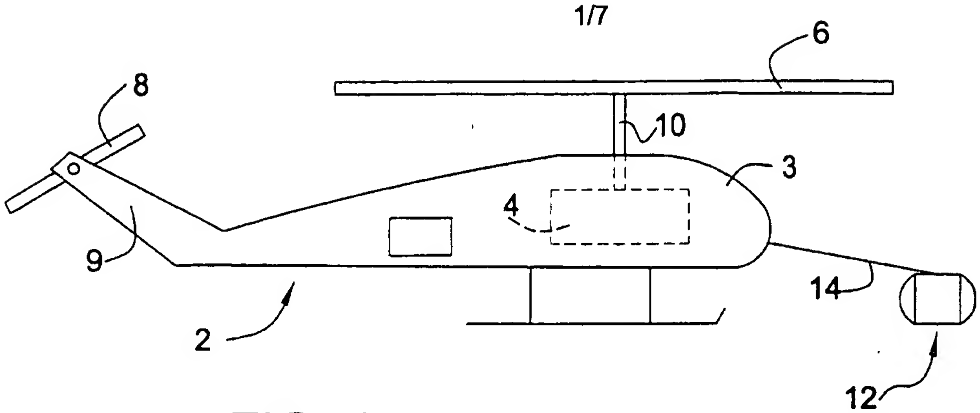


FIG. 1

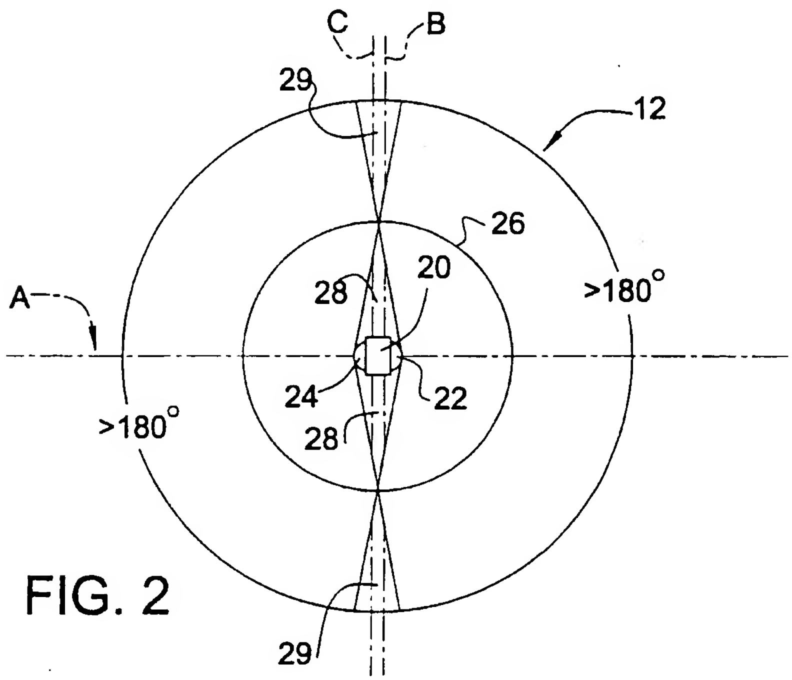


FIG. 2

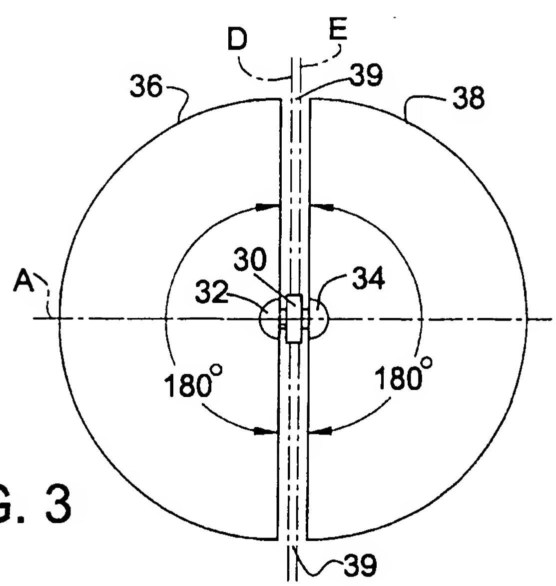


FIG. 3

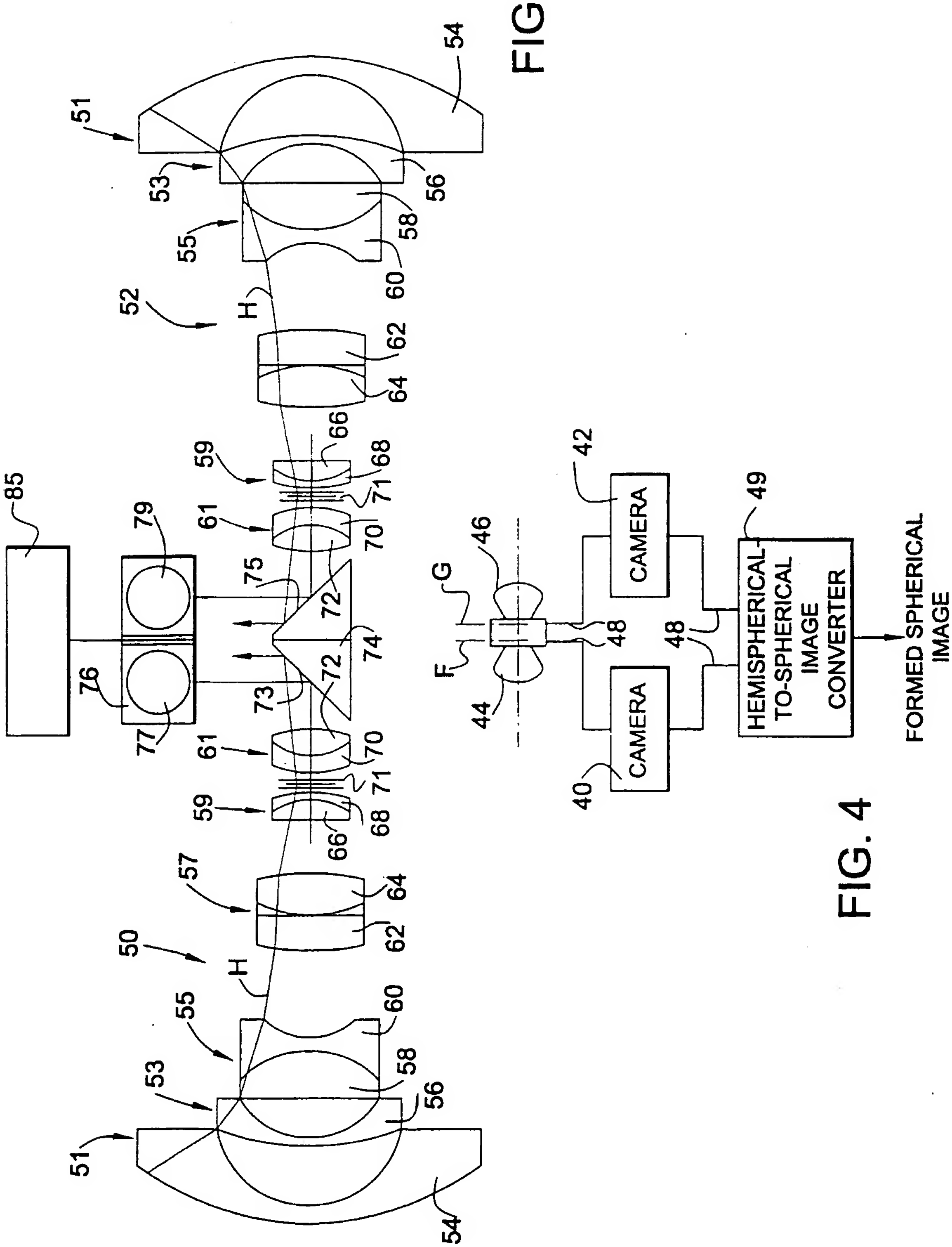

CAMERA
CAMERA
HEMISPHERICAL-TO-SPHERICAL IMAGE CONVERTER
FORMED SPHERICAL IMAGE

FIG. 5

FIG. 4

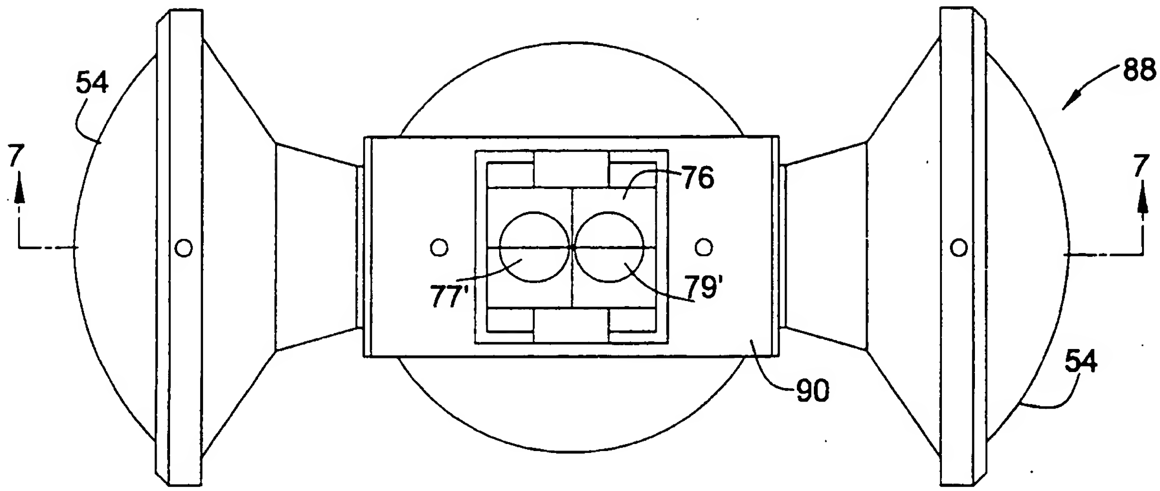

54
7
88
76
7
77'
79'
54
90

FIG. 6

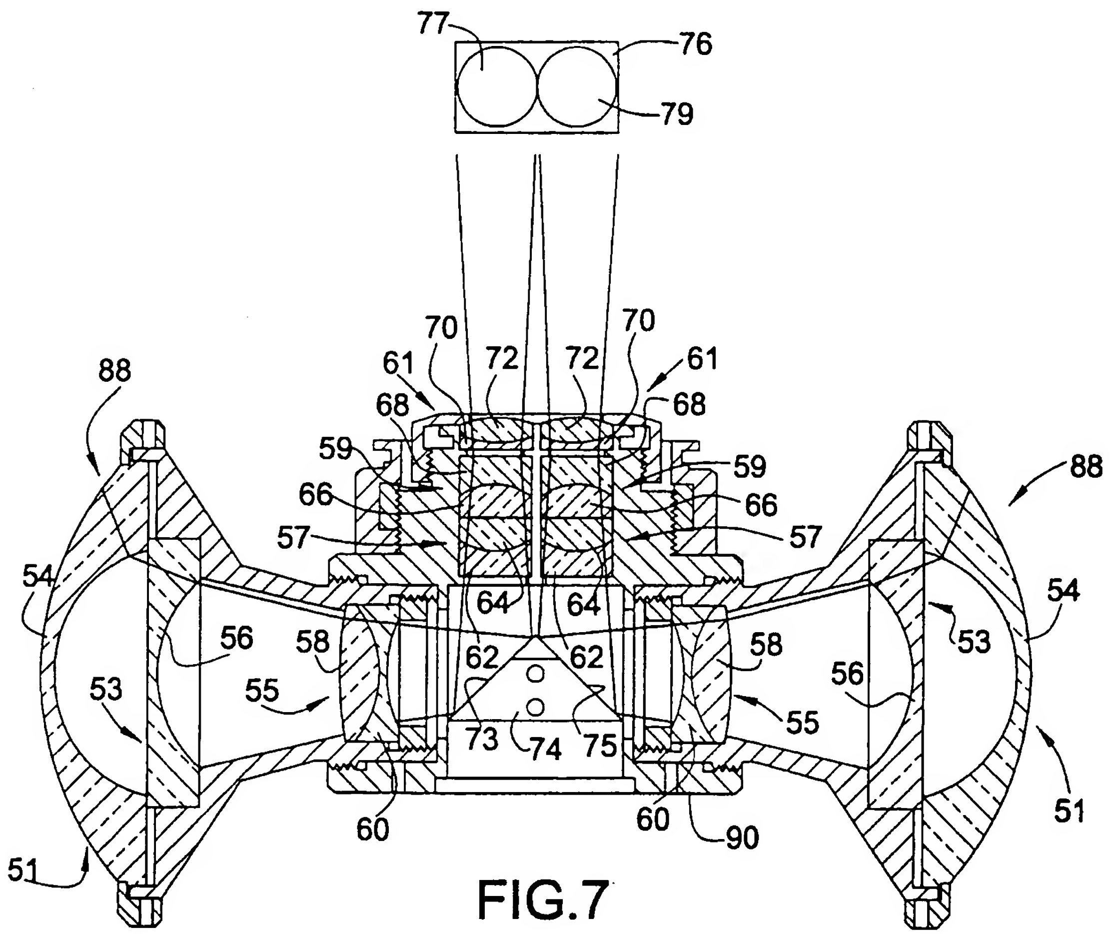

77
76
79
70
70
72
72
61
61
88
68
68
59
59
88
66
66
57
57
54
64
64
54
56
58
58
53
62
62
56
53
55
55
73
74
75
51
60
60
90
51

FIG.7

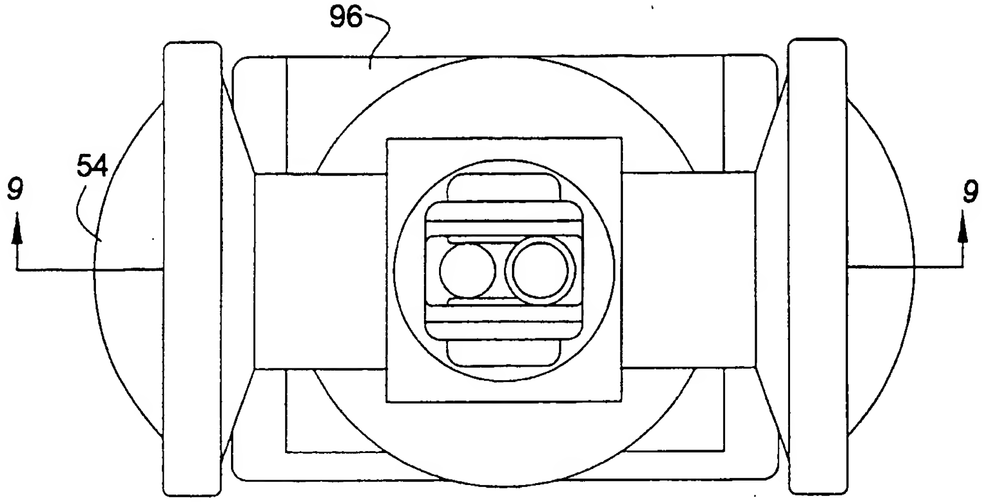

96
54
9
9

FIG. 8

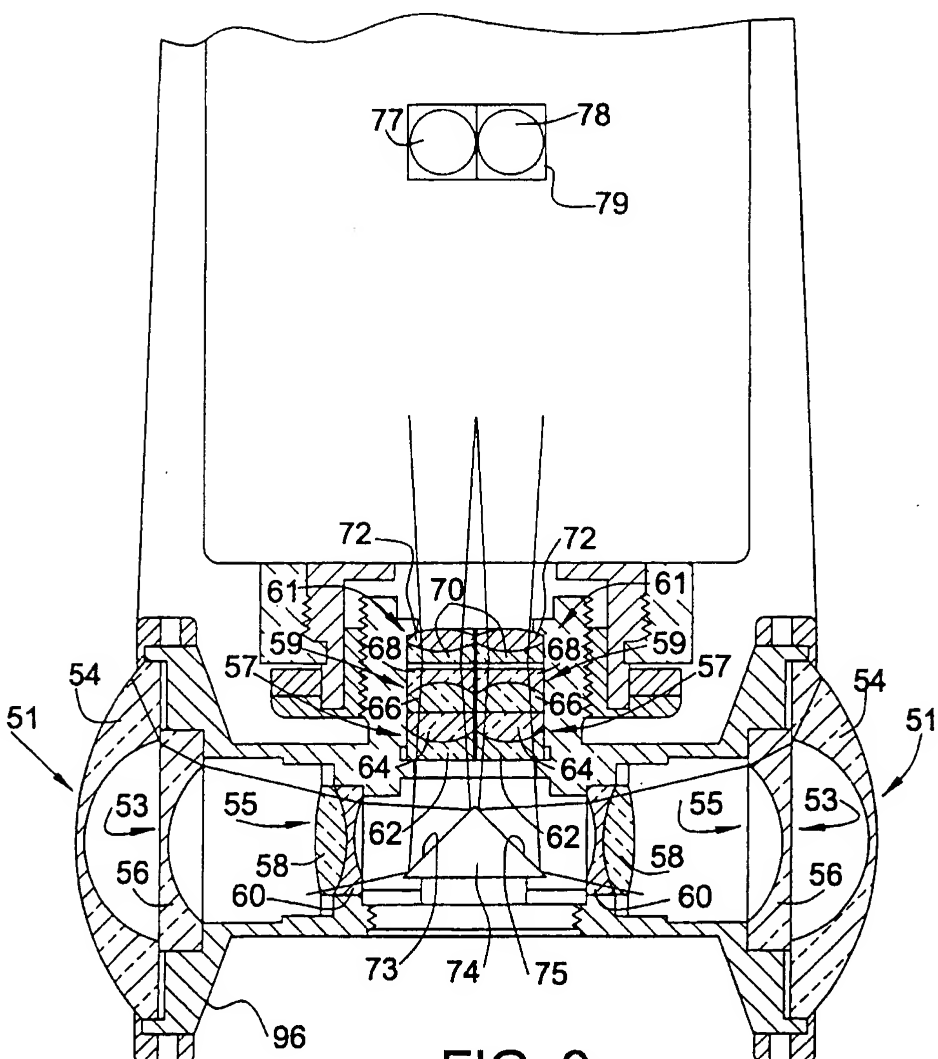

77
78
79
72
72
70
61
61
59
68
68
59
57
57
54
54
51
51
66
66
64
64
53
55
55
53
62
62
58
58
56
56
60
60
73
74
75
96

FIG. 9

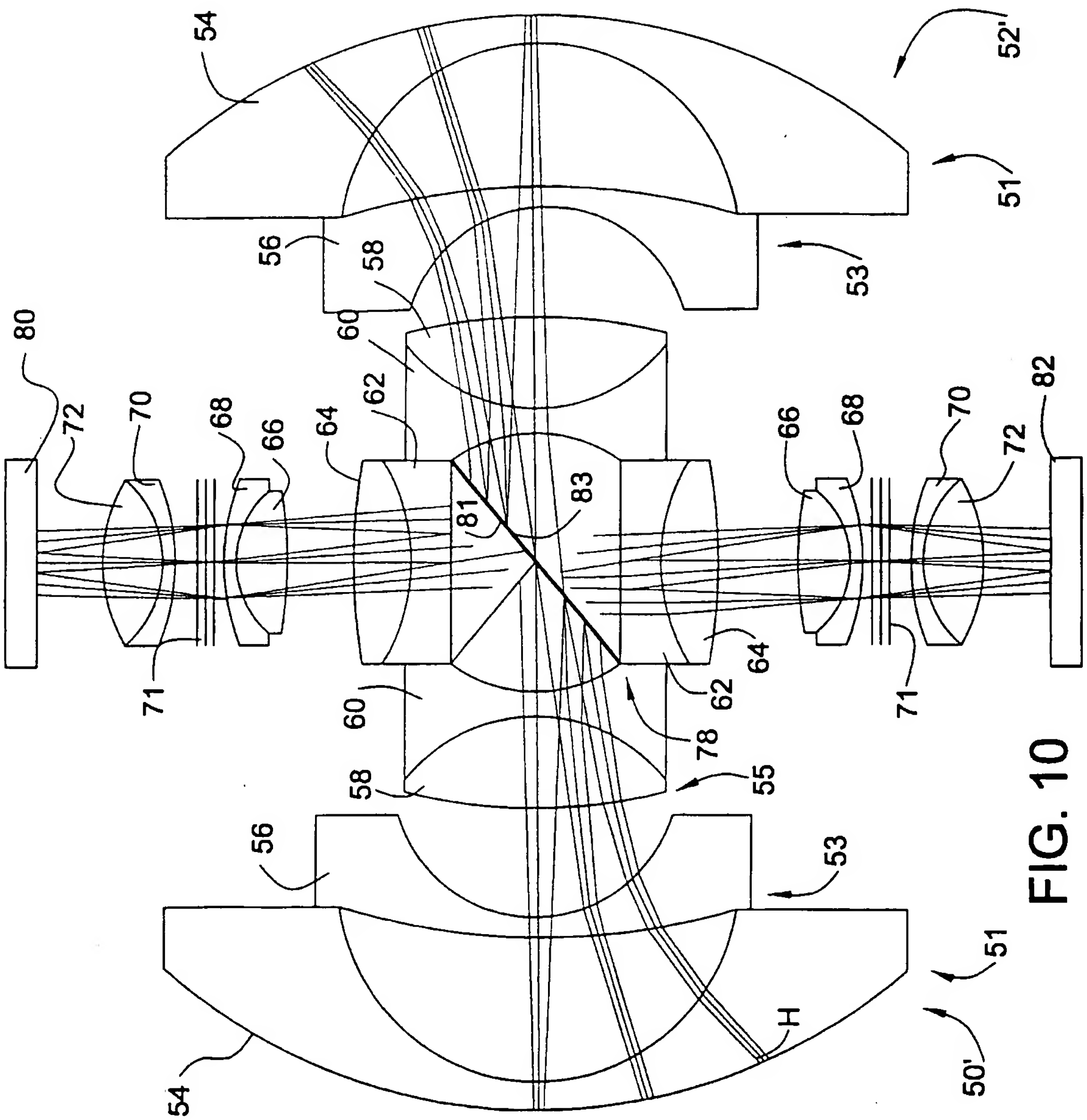
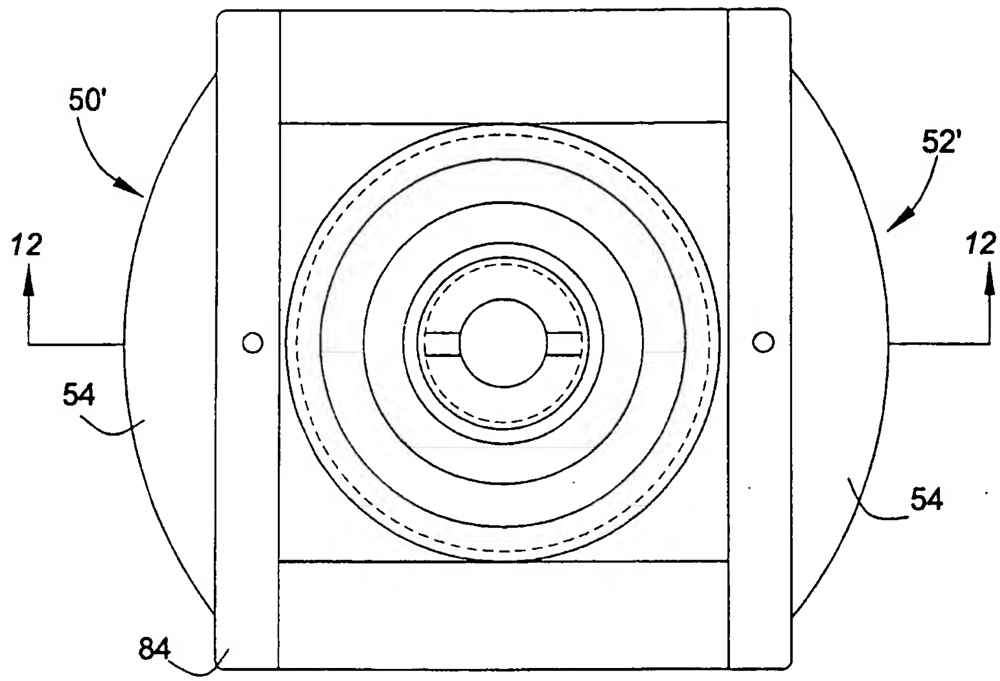
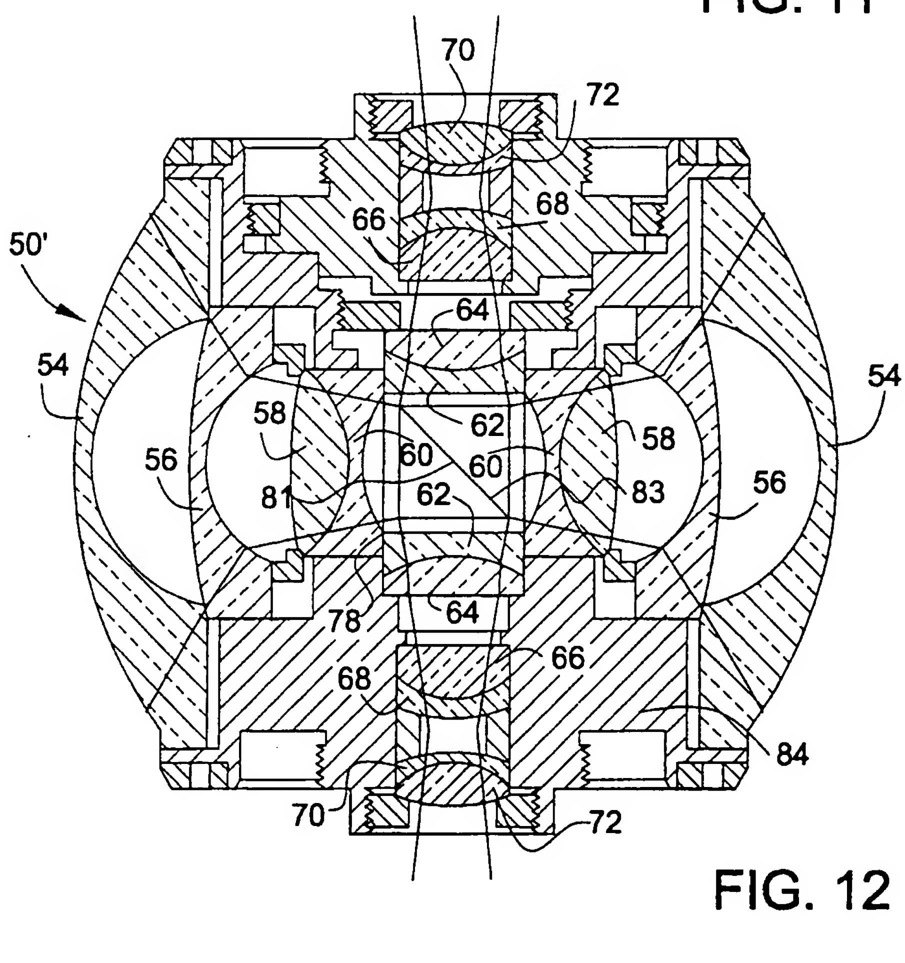


FIG. 10



50'
52'
12
12
54
54
84

FIG. 11



70
72
66
68
50'
64
54
54
58
62
58
56
60
60
56
81
62
83
78
64
66
68
84
70
72

FIG. 12

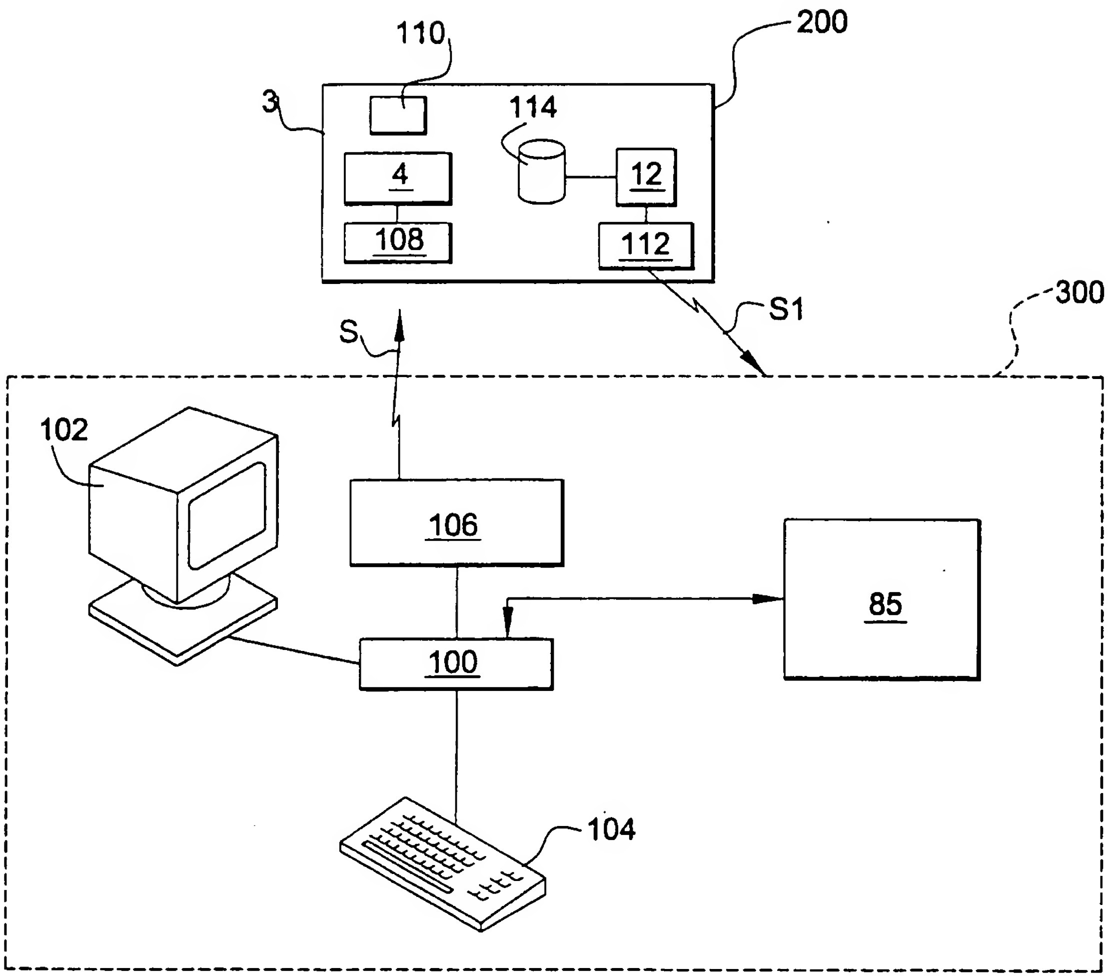


FIG. 13

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/US 00/09469

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04N7/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

PAJ, WPI Data, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	EP 0 607 050 A (ADVANCE VISUAL OPTICS LTD) 20 July 1994 (1994-07-20) column 1, line 35 -column 2, line 5	14 1,18 2
Y A	US 5 481 257 A (BRUBAKER CURTIS M ET AL) 2 January 1996 (1996-01-02) column 2, line 43 -column 3, line 67 column 7, line 1 -column 9, line 28; figures 1-3	1,18 2,15-17
A	US 5 497 960 A (PREVINAIRE EMMANUEL E) 12 March 1996 (1996-03-12) cited in the application column 1, line 46 -column 2, line 47; figure 1 column 4, line 56 -column 5, line 54; figure 6	1,5, 14-18

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 July 2000	14/07/2000
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Fuchs, P

1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/09469

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97 01241 A (OMNIVIEW INC) 9 January 1997 (1997-01-09) cited in the application page 22, line 13 - line 31; figure 3 ---	1,4, 9-11,14, 18
A	US 4 670 648 A (HALL ERNEST L ET AL) 2 June 1987 (1987-06-02) abstract; figures 1,2 ---	1,4,14, 18
A	DE 91 08 593 U (SCHIER JOHANNES) 2 October 1991 (1991-10-02) the whole document ---	1-3,5, 14,17,18
A	WO 89 03076 A (SECRETARY TRADE IND BRIT) 6 April 1989 (1989-04-06) the whole document -----	1,14,18

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 00/09469

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 0607050	A	20-07-1994	DE	69402727	D	28-05-1997
			US	5495370	A	27-02-1996
US 5481257	A	02-01-1996	AT	79049	T	15-08-1992
			AU	611418	B	13-06-1991
			AU	1265988	A	15-09-1988
			BR	8800988	A	11-10-1988
			CA	1338909	A	11-02-1997
			DE	3873378	A	10-09-1992
			DE	3873378	T	08-04-1993
			EP	0281427	A	07-09-1988
			IL	85774	A	15-03-1993
			JP	1020883	A	24-01-1989
			JP	2827011	B	18-11-1998
			KR	9700431	B	11-01-1997
US 5497960	A	12-03-1996	BE	1006178	A	31-05-1994
WO 9701241	A	09-01-1997	US	5990941	A	23-11-1999
			AU	6386696	A	22-01-1997
			EP	0834232	A	08-04-1998
			JP	11508384	T	21-07-1999
			US	5764276	A	09-06-1998
			US	6002430	A	14-12-1999
US 4670648	A	02-06-1987	EP	0198792	A	22-10-1986
			JP	2609518	B	14-05-1997
			JP	61275912	A	06-12-1986
DE 9108593	U	02-10-1991	DE	4031465	A	09-04-1992
			CH	683134	A	14-01-1994
WO 8903076	A	06-04-1989	AU	2427788	A	18-04-1989
			EP	0383783	A	29-08-1990
			ES	2010803	A	01-12-1989
			GB	2231741	A,B	21-11-1990
			PT	88573	A	31-07-1989